(12) **UK Patent Application** (19) **GB** (11) **2 396 011** (13) **A**

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(54) Abstract Title: Analysing noise generated by fluid flow inside production tubing of a well

(57) Acoustic sensors 1 are located between the production tubing and the well casing of a well. The acoustic sensors may be those already installed in the well for providing information about seismic and microseismic events (eg geophones, accelerometers). The output from the sensors 1 is amplified 7 and filtered 8 to isolate the noise generated by the fluid flowing in the tubing. The fluid flow sound data may be obtained by windowing 9 the sensor output either side of the transient sound data, or by subtracting 10 transient sound data from the sensor output. Once processed, the fluid noise is analysed to derive one or more characteristics of the flow (eg velocity, flow rate, composition).
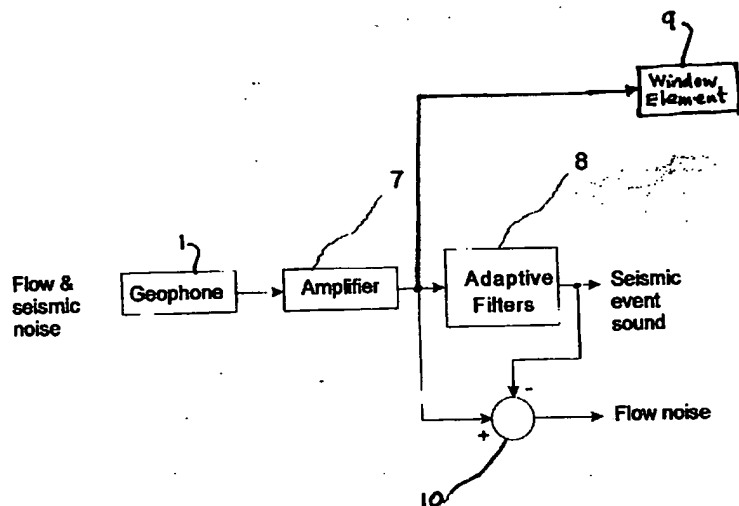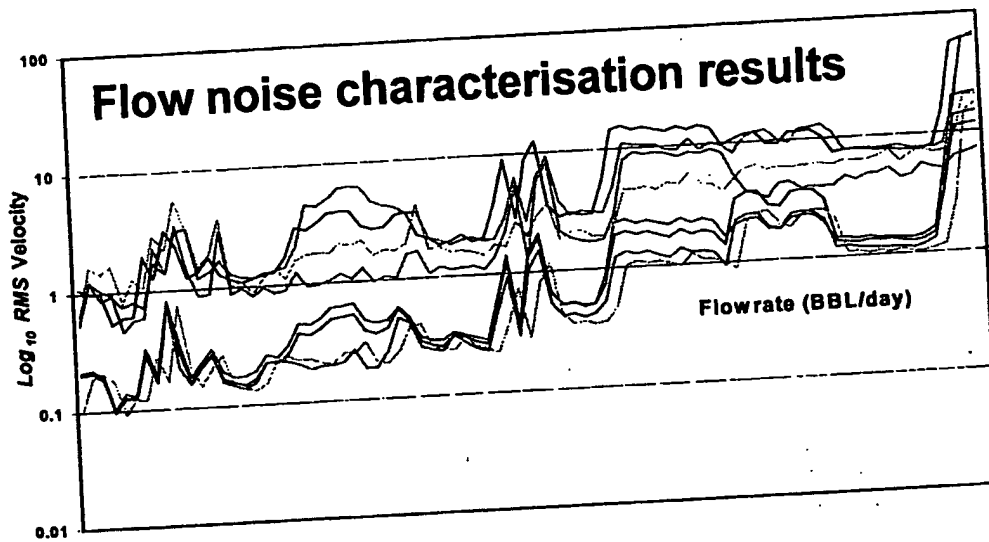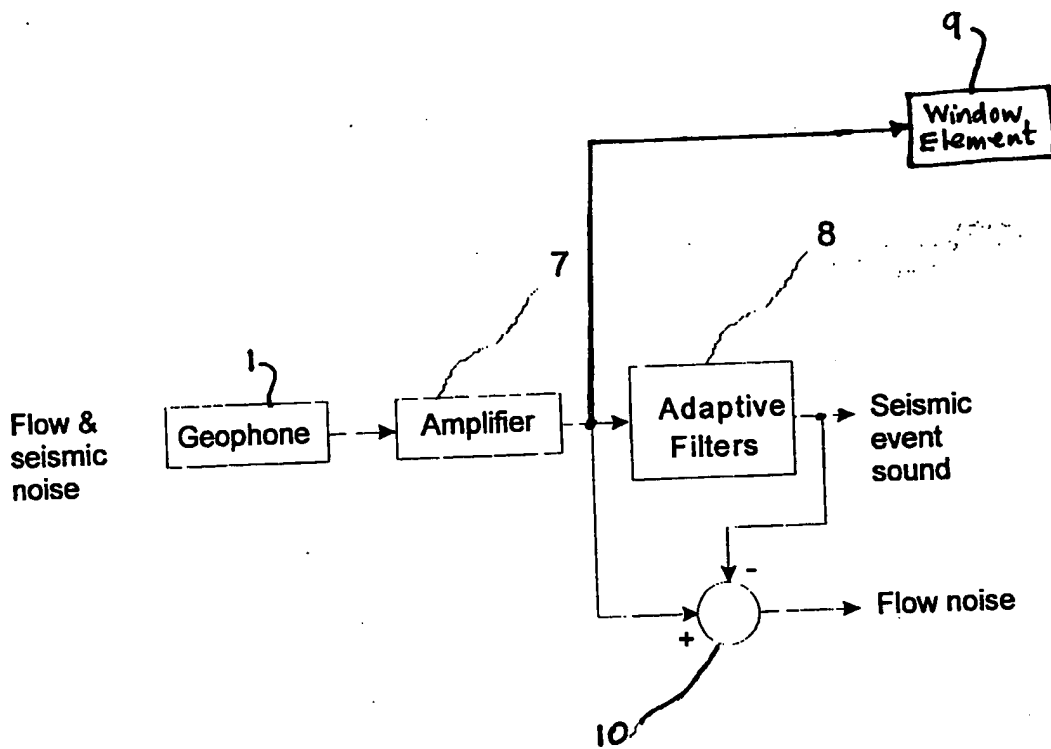
Fig.3

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Fig.1

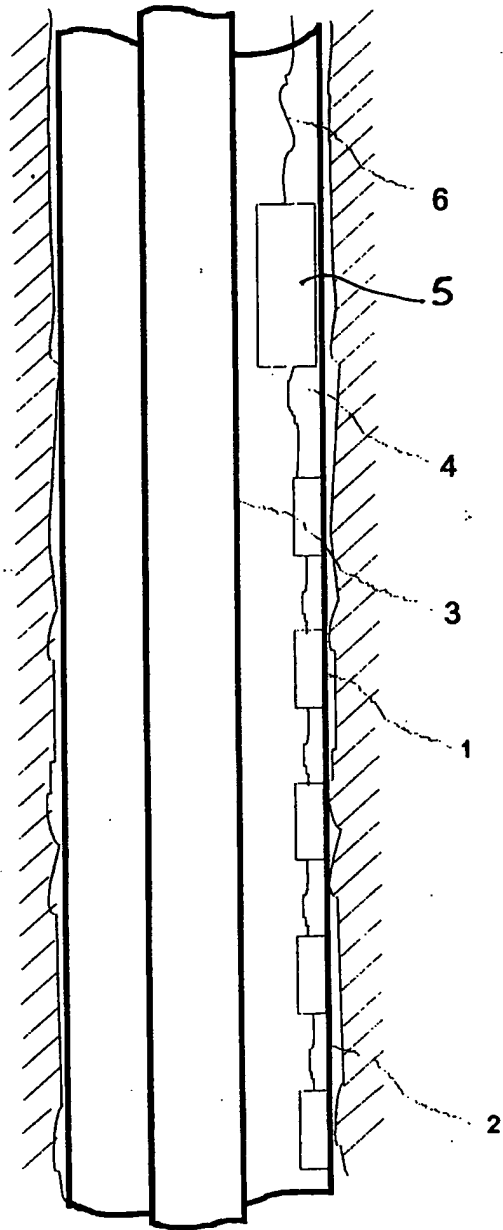

Fig.3

6

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4

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1

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Fig. 2

FLOW NOISE DIAGNOSIS

The present invention relates to a method of and installation for analysing fluid flow inside the production tubing of a well.

A hydrocarbon well-bore generally consists of two approximately concentric tubes, an inner tube, known as the production tubing, acting as a conduit through which fluid can be extracted or injected, and an outer tube, known as the well casing, providing mechanical support for the surrounding rock. One possibility for monitoring fluid flow inside the production tubing of a hydrocarbon well involves the use of in-line flow meters or the like positioned inside the production tubing. However, such devices are intrusive and generally have problems with coping with the variety of contaminants in the extracted fluid which typically in the case of oil extraction include gas, water and sand.

According to one aspect of the present invention, a method of analysing fluid flow inside the production tubing of a well comprising production tubing and a well casing is provided, said method comprising:

a) providing an acoustic sensor between the production tubing and well casing of said well so as to pick up an adequate level of fluid flow sound for analysis;

b) processing the output of said sensor in order to obtain fluid flow sound data substantially free of seismic, microseismic and other unrelated transient sound data; and

c) analysing said fluid flow sound data so as to derive one or more characteristics of the fluid flow therefrom.

According to another aspect of the present invention, an installation for analysing fluid flow inside a production tubing of a well is provided, said installation comprising:

a) an acoustic sensor positioned between the production tubing and a well casing of said well so as to pick up an adequate level of fluid flow sound for analysis; and

b)   data processing means for processing the output of said sensor in order to obtain
        fluid flow sound data substantially free of seismic, microseismic and other
        unrelated transient sound data and analysing said fluid flow sound data so as to
        derive one or more characteristics of the fluid flow therefrom.

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Thus the present invention is based on the concept of recording the noise generated by the
fluid flow with at least one suitably positioned acoustic sensor, processing the recorded
noise to remove any components attributable to sources of sound other than the fluid flow
itself, and then using the flow generated noise as a source of data to allow diagnosis of the

10   flow characteristics in the production tubing.

It is possible to determine characteristics of the fluid flow from the noise produced thereby
because typically the flow of oil, gas, water and sand each produces different acoustic flow
noises, and by processing the complex signal produced by the flow generated noise, for

15   example using frequency content and/or polarisation, it is possible to derive information
on the components of flow. This allows the well operator to have information regarding,
for example, how much different zones of the well are producing, unsteady flow conditions
and the break through of water and/or gas. This information can, in turn, be used to justify
and adjust the well productivity index and applied, using a suitable model, to management

20   of the well flow.

Processing of the or each sensor's outputs in order to separate of the sound data attributable
to fluid flow from that generated by transient events, such as microseismic events, seismic
events and surface operations, may be effected either by windowing data recorded by the

25   sensor either side of the transient sound data (i.e. separating out and ignoring all sound data
recorded at the same time as the transient sound) and/or by subtracting the transient sound
data from the recorded data, such that the remaining sound data is attributable, at least for
the most part, solely to acoustic flow noise.

30   Preferably, the present invention makes use of at least one seismic sensor, which may in
some cases already be installed in side the well for the purpose of providing information

on seismic and/or microseismic events, such sensor then having the dual purpose of seismic signal detection and flow noise recordal.

It is known to fit seismic sensors, such as geophones, hydrophones or accelerometers,
5   inside fluid extraction or injection wells in order to detect the seismic or microseismic signals produced by controlled seismic sources during an active survey, such as Vertical · Seismic Profiling (VSP), or by seismic and microseismic events occurring naturally, or as the consequence of fluid extraction or injection, in the strata surrounding the bore hole. The seismic sensors are normally attached to the casing of the well to provide the best
10   possible acoustic coupling to the strata, as for example illustrated in UK Patent Application No. 0122929.3, and fitted as strings of sensors down the bore so as to provide sufficient spatial sampling of seismic signals, and also in some cases to facilitate steering of the detection sensitivity in different directions.

15   Typically each seismic sensor consists of an arrangement of 3 or 4 individual sensors, as illustrated in GB-A- 2 275 337, the output from the strings of sensors being processed in order to determine details of the strata which can be of use in improving the fluid extraction process efficiency. However the sounds picked up by the seismic sensors are not purely those from seismic events but also comprise background noise generated by the
20   flow of fluid through the production tubing, and also surface operations noise (such as pump noise) transmitted down the well.

In order to minimise the amount background noise reaching such a sensor, great effort has in the past been made to acoustically insulate the geophones from the noise from flow in
25   the production tubing and the surface operations. In order further reduce the effect of background noise of the sensors, considerable signal processing has also been employed to minimise the contamination of the required seismic sound data, as well as the derivation of the further data therefrom, see for example GB-A- 2 372 568. However, once the necessary data regarding the seismic event has been isolated, the remainder of the data,
30   including the data regarding the acoustic noise from the flow in the production tubing, has in the past been discarded.

Where seismic sensors are to be used for seismic signal detection and flow noise recordal, standard seismic processing algorithms can be used to detect and separate seismic, microseismic and other transient sounds from fluid flow noise on the basis of known

5   trigger signals from controlled sources, or using triggering algorithms based on the expected characteristics of the seismic signals (for example amplitude, frequency, phase content or polarisation) at a single geophone or variations across an array of geophones (for example phase delay), the latter being particularly useful for identifying and separating out transient sounds that are generated from surface operations and are transmitted down

10   through the well. Thus where suitably positioned seismic sensors are used, it is possible to separate out two data signals from the sensors' outputs, the first attributable, at least for the most part, to fluid flow noise inside the well, and the second attributable, at least for the most part, to the sound generated by seismic events.

15   An embodiment of the invention will now be described, by way of example, with reference to the following drawings, in which:

Fig. 1 is a graph illustrating the relationship between the flow rate inside the production tubing of a well and the acoustic noise produced thereby;

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Fig. 2 shows, in simplified form, an installation for monitoring fluid flow and at the same time detecting microseismic events; and

Fig. 3 shows, in simplified form, a possible configuration for processing the sensor outputs.

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Fig. 1 shows an example of acoustic noise (RMS noise) dependency on flow rate for a variety of seismic sensors (geophones and accelerometers) attached to different points on the inside of casing and outside of production tubing. The data illustrates the strong dependency of acoustic noise on the flow rate and the potential for using flow induced

30   acoustic noise to characterise flow (e.g. velocity, flow rate, composition).

Fig. 2 shows an installation comprising a plurality of geophones 1 fitted as strings (only one string of five geophones shown) located against well casing 2 of a production well comprising the well casing 2 and production tubing 3. Despite the mechanical isolation of the geophones 1 from the production tubing 3, the sensitivity of the geophones 1,

5   distance between the geophones 1 and production tubing 3 and well bore environment are such that an adequate level of flow noise is still detected by the geophones. The geophone 1 outputs are fed, via electrical connections 4, to a processing unit 5, that is also located against the well casing 2 within the borehole (though it could equally be located top-side). Once processed, the sound data is then transmitted to the well head by cables 6, which may

10   be electrical or optical.

Fig. 3 illustrates a possible form of signal processing that can be carried out on a geophone 1 output in order to separate the data into fluid flow noise and seismic / microseismic signals. The output of the geophone is first amplified by an amplifier 7 and then passed

15   through an adaptive filters 8, these elements being the same elements that are employed in the standard use of the geophones for seismic detection, in order to isolate any seismic signals present in the data which can then be analysed for the purpose of deducing the characteristics of the seismic event. At the same time, a copy of the geophone output which has been amplified but not filtered is processed in one of two ways in order to

20   isolate a fluid flow noise signal. The first option is to pass a copy of the geophone output through a windowing element 9 which carries out a windowing operation wherein all acoustic data detected at the same time as a seismic signal is simply excised such that the data remaining represents, at least for the most part, only fluid flow noise. The second option is to pass the copy of the geophone output through a subtraction element 10 which

25   cancels the seismic signal from the copy of the geophone output, such that the data remaining represents, at least for the most part, only fluid flow noise.

CLAIMS:

1. A method of analysing fluid flow inside the production tubing of a well comprising production tubing and a well casing, said method comprising:

   a) providing an acoustic sensor between the production tubing and well casing of said well so as to pick up an adequate level of fluid flow sound for analysis;

   b) processing the output of said sensor in order to obtain fluid flow sound data substantially free of seismic, microseismic and other unrelated transient sound data; and

   c) analysing said fluid flow sound data so as to derive one or more characteristics of the fluid flow therefrom.

2. A method according to claim 1, wherein said fluid flow sound data is obtained by windowing the sensor output either side of said transient sound data.

3. A method according to claim 1, wherein said fluid flow sound data is obtained by subtracting said transient sound data from the sensor output.

4. A method according to any preceding claim, wherein said sensor is a seismic sensor positioned so as to pick up seismic and/or microseismic sounds, the output of said sensor being processed to obtain seismic and/or microseismic sound data substantially free of unrelated transient sound data and fluid flow sound data.

5. A method according to any preceding claim, wherein the or each characteristic of the fluid flow is used for management of the well.

6. An installation for analysing fluid flow inside a production tubing of a well, said installation comprising:

a)   an acoustic sensor positioned between the production tubing and a well
       casing of said well so as to pick up an adequate level of fluid flow sound
       for analysis; and

b)   data processing means for processing the output of said sensor in order to
       obtain fluid flow sound data substantially free of seismic, microseismic and
       other unrelated transient sound data and analysing said fluid flow sound
       data so as to derive one or more characteristics of the fluid flow therefrom.

7.   An installation according to claim 6, wherein the data processing means obtains
       said fluid flow sound data by windowing the sensor output either side of said
       transient sound data.

8.   An installation according to claim 6 or 7, wherein the data processing means
       obtains said fluid flow sound data by subtracting said transient sound data from the
       sensor output.

9.   An installation according to any one of claims 6 to 8, wherein said sensor is a
       seismic sensor positioned so as to pick up seismic and/or microseismic sounds and
       the data processing means is adapted to process the output of said sensor in order
       to obtain a seismic and/or microseismic sound data substantially free of unrelated
       transient sound data and fluid flow sound data.

10.   An installation according to any one of claims 5 to 9, wherein the data processing
       means comprise one or more data processors located within the well and/or topside.

11.   A method substantially as hereinbefore described with reference to Figures 1, 2 and
       3.

12.   An installation substantially as hereinbefore described with reference to Figures 1,
       2 and 3.

Patents Act 1977 : Search Report under Section 17

Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular relevance	
X;Y	X:1,5,6,10 Y:4,9	WO 2001/055553 A1	(Shell International Research) See page 4 line 34 - page 5 line 6, page 22 lines 31-33, page 25 lines 17-22 and figure 8
Y	4,9	GB 2273359 A	(Schlumberger Limited) See abstract
A		www.sensa.org/pdfs/acousticsensor.pdf, Acoustic Flow Sensing	

Categories:

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.

Field of Search:

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC^V:

G1G,G3R

Worldwide search of patent documents classified in the following areas of the IPC^7:

G01V, E21B

The following online and other databases have been used in the preparation of this search report:

WPI, EPODOC, JAPIO